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# Occupational Health in Ontario

Volume 7, Number 1, Winter 1986

*Scleroderma and Raynaud's Phenomenon of Occupational Origin*

*Health Survey of Foreign-Posted Workers at an Industrial Utility*

*Farming, Pesticides and Occupational Health*

*Styrene Exposure in the Reinforced Plastics Industry in Ontario*

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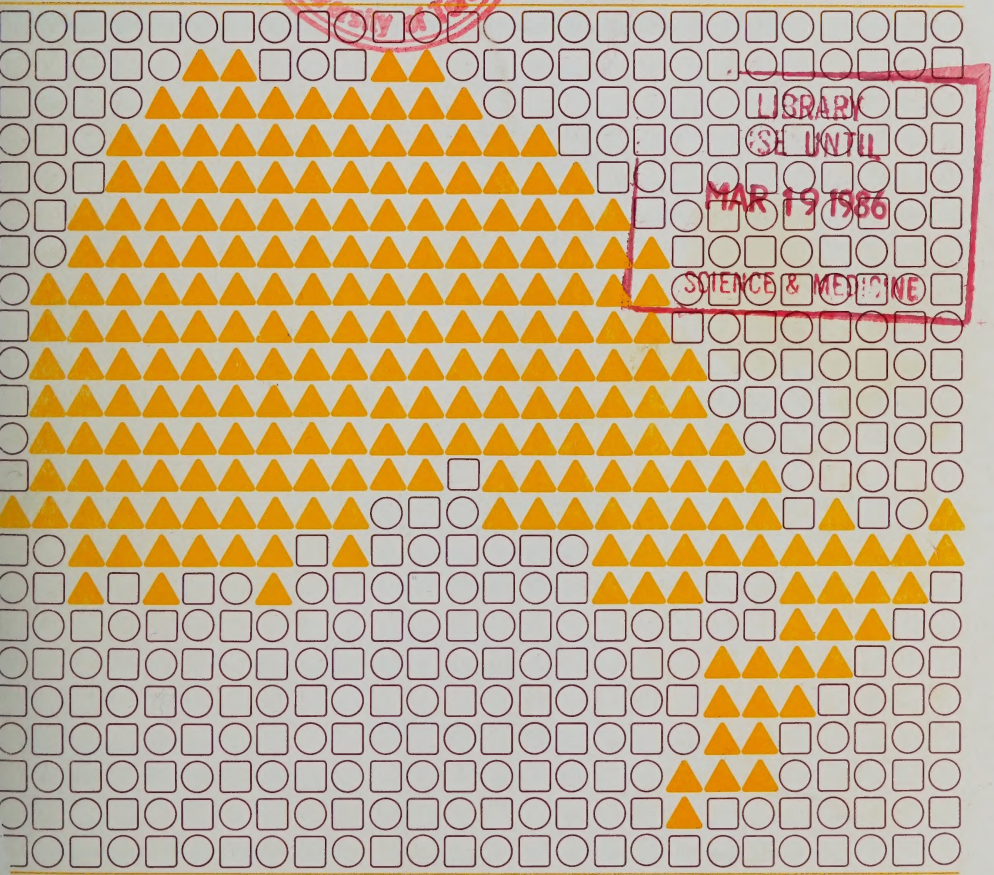

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# Occupational Health in Ontario

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# Scleroderma and Raynaud's Phenomenon of Occupational Origin

## Summary

*This paper reviews the classification and clinical features of the sclerodermas and details the evidence required for a correct differential diagnosis when Raynaud's phenomenon of occupational origin with finger-pulp ulceration is being evaluated for compensation purposes.*

Cutaneous changes manifested by dermal fibrosis and fixation of the skin to underlying structures were first described by Carlo Curzo[1] of Naples in 1753. It was not until 1900 that it was realized that this thickening and induration of the skin also involved, in many cases, the visceral organs as part of the same process and that subsequent dysfunction of the organs was rapidly progressive and frequently fatal. Later, it was recognized that the pathological changes occurring in the vascular system, especially in the fingers, resembled those found in patients with Raynaud's disease or constitutional white finger, producing intermittent attacks of vasospasm precipitated by exposure to cold. It was indistinguishable from the characteristic three-phase colour change seen in the fingers in Raynaud's disease—pallor (or blanching), cyanosis and, finally, reactive hyperaemia or red flush. Prolonged ischaemia from frequent, prolonged attacks will lead to ulceration of the skin of the terminal phalanges and even finger pulp tissue necrosis and gangrene.[2,3]

## Raynaud's Phenomenon

Raynaud's disease, or constitutional white finger, is the term reserved for the spasmodic stress, or cold-induced white finger, found in the community (of which 90 per cent were females) first described by Dr. Maurice Raynaud[4] in 1862. The term Raynaud's phenomenon refers to a similar clinical syndrome with white fingers, cyanosis and hyperaemia following exposure to cold in subjects having a known secondary cause.

In severe cases of Raynaud's phenomenon of occupational origin (also known as vibration-induced white finger), resulting from the extensive use of hand-held vibratory tools, ulceration of the pulps of the terminal digits may be found as a complication of Stage 3 (Taylor-Pelmear Classification).[5] For diagnostic and compensation purposes in these industrial cases, it is necessary to exclude in the differential diagnosis all other causes of white finger. In the extensive list of possible causes[6] connective tissue disorders predominate and must be differentiated. Scleroderma is the most common disorder found in practice.

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## Classification of Scleroderma

A simplified classification of scleroderma is shown in Table 1.

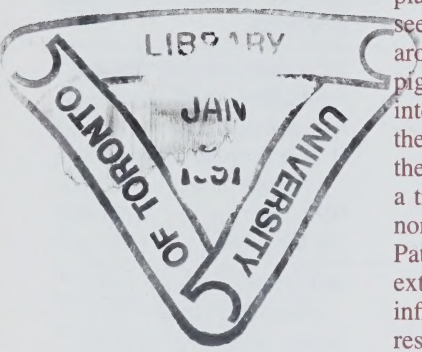
**Table 1** **Classification of Scleroderma**

| Type | Features |
|---|---|
| Systemic Sclerosis (isolated acrosclerosis to progressive and diffuse) | Skin and Internal Organs<br>(a) Diffuse skin involvement<br>(b) Gastrointestinal tract<br>(c) Lungs<br>(d) Heart<br>(e) Kidney |
| Localized Scleroderma | Morphoea – Single or multiple plaques<br>Linear Scleroderma – en coup de sabre |
| Crest Syndrome | Limited skin involvement<br>Raynaud's Phenomenon<br>Sclerodactyly<br>Telangiectasia<br>Calcinosis<br>Eosinophilia |
| Eosinophilic Fasciitis | Limited skin involvement<br>Eosinophilia<br>Hypergammaglobulinemia |
| Mixed Connective Tissue Disease | Scleroderma (systemic)<br>Polymyositis<br>Systemic lupus erythematosus (SLE) |

## Clinical Features of the Sclerodermas

### 1. Systemic Sclerosis

The early phase is characterized by oedema of the face, forearms, hands and fingers. The oedema is followed by the classical fibrotic stage, and the fibrosis is dense enough to restrict movement of arms, legs and hands. The course is variable, but, usually, slowly progressive. Inability to extend the fingers fully (the digits remain semi-flexed) gives rise to the term *sclerodactyly*. The loss of elasticity and hardening of the skin over the face, in




particular, the nose, results in a pinched and beak-like nose contour, with restricted mouth opening and radial furrowing at the corners of the mouth. *Telangiectasiae*, defined as circumscribed collections of vascular tissue in the form of macules from one to several millimeters in diameter, are often present on the cheeks and around the mouth, but are pathonomonic if found on the palmar or plantar surfaces of the hands and feet. *Calcinosis* may be seen as a deposit of hydroxyapatite crystals located around joint capsules. A diffuse increase in melanotic pigmentation may extend over the entire skin surface interspersed with areas of depigmentation (often seen on the fingers). The depigmentation occurs with sparing of the pigmentary cells around the hair follicles, so it is not a true vitiligo. The skin over the metacarpal joints, normally in folds, becomes smooth and shiny. Pathological changes in the vascular system of the extremities give rise to Raynaud's phenomenon. A mild inflammatory arthritis, usually symmetrical and resembling rheumatoid arthritis, may occur with a mild degree of bone erosion. *Acro-osteolysis*, similar to that seen in patients exposed to the monomer in the polymerization of vinyl chloride, is a skeletal complication with resorption of the bone of the terminal phalanges, which results in shortening of the digits. Pulmonary involvement, with decreased carbon monoxide diffusion capacity as an early finding, occurs in 50 per cent of cases, first producing chronic pulmonary fibrosis followed by pulmonary hypertension.[7,8] Manometric studies have demonstrated diminished peristalsis in 90 per cent of cases, but only 50 per cent will have oesophageal involvement with symptoms of reflux or dysphagia.

Renal involvement is caused by deposition of collagen in the blood vessels and carries a poor prognosis because of the secondary proteinuria and hypertension. The latter is often uncontrollable, and renal disease with scleroderma is often a fatal process.

Systemic sclerosis is a disease of unknown aetiology. Women between the ages of 40 – 60 are affected three to five times more often than men. In five counties of England with a total population of 3,300,000, 89 cases were identified over a 10-year period.

Because there is so little known about the underlying defect in the collagen mechanism, there is no specific treatment. Surgical intervention (sympathectomy), resperine and ganglionic blocking agents, penicillamine and immuno-suppressive drugs have all failed.

## 2. Morphoea or Localized Scleroderma

Localized scleroderma, or morphoea, distinguishable histologically from scleroderma, would appear to be a separate disease with changes limited entirely to the skin. The lesions that develop in morphoea may be erythematous at the outside, but eventually become white and porcelain-like with high binding. They remain circumscribed in localized areas and do not tend to involve all fingers as would be typical of acrosclerotic scleroderma. As well as the erythematous plaques found on the face, trunk and extremities, chronic painful skin ulcerations appear on the pulps of the terminal phalanges. These may progress in subjects with severe Raynaud's phenomenon[9] to tissue necrosis. Patients with morphoea do not have Raynaud's phenomenon unless it is a disorder that they have developed as a separate disease entity. Therefore, a patient with vasospastic disease and sclerodermatous lesions is more likely to be suffering from acrosclerotic scleroderma than morphoea. In children, the cutaneous lesions appear in dermatomal distribution ending abruptly in the midline (*en coup de sabre*). Spontaneous resolution of these various forms of cutaneous plaques may occur over a period of years, leaving residual atrophy and pigmentation of the skin.

## 3. The Crest Syndrome

The crest syndrome is a variant of acrosclerotic scleroderma, with skin involvement limited to the hands and face so it tends to have a good prognosis. The complete crest syndrome will include calcinosis, Raynaud's phenomenon, sclerodactyly, telangiectasia and eosinophilia.

## 4. Eosinophilic Fasciitis

Eosinophilic fasciitis, originally reported as a syndrome distinct from scleroderma,[10] now appears to be a variant of the crest syndrome. The characteristic features are rapid onset of thickened and oedematous cutaneous induration of the extremities and, less frequently, the abdomen, eosinophilia, hypergammaglobulinemia, fasciitis with inflammation and fibrosis in the subcutis and underlying fascia. Some cases also have Raynaud's phenomenon, oesophageal dysmotility, restrictive lung disease, diffuse hyperpigmentation, synovitis, flexion

contractures and dermal sclerosis.[11] The prognosis is not entirely clear, but initial high-dose steroids suppress disease activity.[12]

## 5. Mixed Connective Tissue Disease (MCTD)

Patients with this condition have features suggestive of systemic scleroderma, systemic lupus erythematosis and polymyositis. The clinical features are diverse and include polyarthralgia resembling rheumatoid, Raynaud's phenomenon, oesophageal hypomotility, abnormal pulmonary function with decreased diffusion capacity, swollen hands and myositis. The age range is five to 80 years and 80 per cent of patients are female. The course of MCTD is variable and, in some patients, chronic.

Abnormal laboratory results commonly include elevated sedimentation rates, leukopenia and diffuse hypergammaglobulinemia. Rheumatoid factor tests are positive in about 50 per cent of patients. Serological tests for antinuclear antibodies provide the most helpful diagnostic findings in patients with MCTD. The most typical finding is a strongly positive test for an antibody to an extractable nuclear antigen. Sera containing antibodies to RNP antigen alone are most commonly seen in MCTD. Antibodies to SM antigen, infrequent in MCTD, are common in systemic lupus erythematosis.

There is no definite demarcation between many of the connective tissue disorders so it is difficult to avoid overlap in the differential diagnosis. For those occupational physicians primarily concerned with the correct diagnosis of Raynaud's phenomenon of occupational origin, it is sufficient to merely exclude all forms of connective tissue disease without differentiation, but for compensation purposes, an accurate diagnosis within the connective tissue disorders group is desirable. Recent research has concentrated on developing criteria to permit comparisons of diagnoses from different centres throughout the world and to evaluate clinical investigations and therapeutic trials. For this purpose, a subcommittee of the American Rheumatism Association was set up and reported[13] in 1980. The diagnostic criteria proposed from a study of 812 patients from 19 medical centres in the U.S.A. were:

a) Major criterion – proximal scleroderma.
b) Two or more of the following minor criteria:
   1) sclerodactyly
   2) digital pitting scars of finger tips (ulceration)
   3) bilateral basilar pulmonary fibrosis
   4) Raynaud's phenomenon.

When the above criteria were applied to a population of suspected cases for a diagnosis of systemic sclerosis, the sensitivity was 97 per cent and specificity 98 per cent. No such classification criteria or guidelines have been set up for localized scleroderma or the crest syndrome.

Patients with Raynaud's phenomenon arising from secondary causes such as vibration, thoracic outlet syndrome, neurological diseases, trauma, lacerations, toxins, etc. may have finger ulcerations as a late complication. Then a dilemma arises in distinguishing localized scleroderma, with its pitted indurated finger pulp ulcerations and, in particular, Raynaud's disease as the cause of the ulceration, from the tissue necrosis arising from the digital ischaemia from long-term exposure to vibration of hand-held tools.

In pure scleroderma cases, without Raynaud's phenomenon, the blood vessels in the plaques and in visceral organs show a reduction in diameter with hyalinization of arterioles and perivascular lymphocytic infiltration. Burch[14] and his colleagues have confirmed, in scleroderma, extensive devascularization accompanied by progressive damage to the medial and intimal coats of the vessels and incorporation of collagen fibrils within their basement membranes. This deposition of collagen fibrils suggests that the regulation of collagen synthesis by scleroderma fibroblasts may be defective. Furthermore, scleroderma dermal fibroblasts produce more collagen containing type V (A and B) chains than do normal dermal fibroblasts. Other experimental studies have led to the conclusion that abnormalities of cellular immunity may exist in scleroderma. The T lymphocytes from scleroderma patients exhibit some evidence of hypersensitivity to collagen and to skin extracts in certain *in vitro* systems.[15]

Positive tests for antinuclear antibodies are found in approximately 95 per cent of patients with scleroderma.

## Raynaud's Phenomenon of Occupational Origin – The Hand-Arm Vibration Syndrome

It is now realized that, in addition to digital arterial spasm and sensitivity (producing white finger attacks), there is sensory loss from damaged digital nerve endings as well as musculoskeletal effects such as reduced grip strength.[16] Pathological changes are found in the walls of the digital arteries and arterioles (intimal and medial fibrosis), resulting in narrowing of the lumen of these vessels.

In a recent survey[17] of vibration-exposed workers, 78 cases with hand-arm vibration syndrome were examined

for medico-legal purposes. In this total there were four cases with finger-pulp ulceration, the details of which are shown in Table 2.

**Table 2** **Data Relating to Four (4) Vibration-Exposed Subjects With Ulceration of the Pulps of the Terminal Phalanges**

| Industrial Process | Case | Total Vibration Exposure Time (Years) | Age (Years) | Stage (Taylor-Pelmear) |
|---|---|---|---|---|
| Copper Swager | FW | 2 | 42 | 4 |
| Pneumatic Hammer | WB | 14 | 46 | 4 |
| Pneumatic Hammer (Road Ripper) | RP | 15 | 45 | 4 |
| Pneumatic Hammer (Road Ripper) | FP | 12 | 53 | 4 |

Prior to entering employment there were no complaints of cold hands, white fingers or abnormal circulation by any of these four subjects. Furthermore, there were no near relatives with adverse reactions to cold, so it is not likely that primary Raynaud's disease was the cause. In the occupational history there were no causes of white finger (secondary) other than vibration. In the general medical examination there was no evidence found of any type of scleroderma – no plaques, oedema of arms or hands, dysphagia, oesophageal reflux, dyspnoea, arthritis, and no skin changes on the face, mouth or forehead. Clinical examination for scleroderma was negative, with the exception of one subject (WB), who was unable to extend his fingers (10° flexion).

## Conclusion

In reviewing the clinical classification of scleroderma in relation to cases of finger-pulp ulceration seen in advanced cases of the hand-arm vibration syndrome, it will be apparent that, for compensation purposes and for a correct differential diagnosis, the following evidence is required:

1. measurement of the vibration characteristics of the hand-held tool (whilst operating) in terms of vibration levels (metres per $sec^2$) and frequencies

(Hertz), together with the vibration exposure time of the subject (shift, week, year). Comparison may then be made with ISO/DIS/5349 DRAFT international standard[18] guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration, 1984. A second guideline[19] has recently been proposed (1985) by the American Conference of Governmental and Industrial Hygienists on vibration limits and durations of exposure;

2. clinical judgement with respect to the cumulative energy entering the hands and relating this to the Stage assessment in the Taylor-Pelmear classification (Stages 3 and 4). If the subject continues with exposure to hand-arm vibration, the characteristic intermittent vasospasm (giving rise to white-finger attacks) tends to be replaced by permanent cyanosis of the digits (acrocyanosis stage). It is following this phase that skin and pulp ulceration is most often seen, and the ulceration following ischaemia requires to be distinguished from that due to burns. Temperature appreciation is lost in some of these patients;

3. laboratory investigations as follows:
   1) Full blood count and differential
   2) ESR
   3) Rheumatoid Fixation Test (low titres of rheumatoid factor activity are found in 25 per cent of scleroderma patients; high titres in 50 per cent of MCTD patients)
   4) Cryoglobulin determinations
   5) Serum protein electrophoresis
   6) Specific antibodies for scleroderma[20,21] (antibody to Scl-70 antigen; antibody to centromere and antinuclear antibody. The anticentromere is primarily seen in patients with the crest syndrome variant. Antibodies to RNase-sensitive extractable nuclear antigens (RNP alone) is most commonly seen in MCTD).

The ultimate opinion of the physician, following this protocol, may not be as positive (or as certain) as a court of law or compensation board would wish, but this is the state of the art at the present time.

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**Résumé**

Ce document étudie la classification et les manifestations cliniques des sclérodermies et décrit les indices requis pour établir un diagnostic différentiel correct lors de l'évaluation, aux fins de versement d'indemnités, du phénomène de Raynaud d'origine professionnelle se manifestant par une ulcération du bout des doigts.

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# Health Survey of Foreign-Posted Workers at an Industrial Utility

## Summary

*The health experience of an industrial utility's foreign-posted returnees is described. Health outcomes were generally favourable. Self-limited diarrhea and fever of less than three days' duration were the most common complaints. Depression, boredom and anxiety occurred occasionally among workers and their spouses. Workers abroad had a tendency to increase their alcohol consumption. Driving in the developing world was found to be hazardous. Worker recommendations, and differences between foreign postings, are reported.*

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Corporate physicians are increasingly required to assess employee fitness for foreign posting to the developing world. Information on currently required or recommended immunizations[1,2,3] and other preventive measures[4–7] is readily available, but few publications comment upon the health experience of these workers. The objectives of this study were to evaluate the living conditions and health outcomes of foreign-posted workers assigned to supervisory or middle management positions abroad.

## Materials and Methods

Sixty-three employees of a Canadian industrial utility were identified as having worked overseas between January 1980 and December 1984. They were sent a covering letter explaining the health survey, a four-page foreign-postings health questionnaire and a return envelope addressed to the corporation's Health Services Department. Employees were not asked to give identifying information. When an employee package was returned 'location unknown', the Personnel Department was asked to determine the employee's correct work location, and the mailing was redirected.

## Results

One employee did not respond to the questionnaire because of extended sick leave. For the remaining 62 eligible respondents, 56, or 90.3 per cent, of the questionnaires were returned. Health outcomes were recorded for a total of 210 individuals. The return rate for employees who had worked in South Korea was 83 per cent; for Pakistan, Argentina and Ghana the return rate was 100 per cent. (No other countries were represented.) All returnees were male. The mean length of stay abroad was 2.5 years with a range of 10 months to 5.8 years. All respondents but one were stationed in rural areas.

## Features of Foreign-Posted Workers and Their Families

The mean age of workers at the time of overseas departure was 36.1 years (range 27 – 54 years). Only one respondent went abroad unaccompanied by his spouse and only one employee was unmarried. The mean age of the accompanying spouse at the time of foreign posting departure was 32.5 years (range 19 – 49 years). Ten married employees went abroad without children. Three of these couples had a child while away and another couple adopted two children during their stay.

Altogether, 100 children accompanied their parents overseas. Their ages at departure ranged from six months to 16 years. Sixty-five per cent of the children were less than 10 years old.

## Illnesses in Foreign-Posted Workers and Their Families

Almost every family experienced diarrhea of less than one week's duration; nineteen people in 10 families had diarrhea lasting longer than three weeks. One case of bloody diarrhea was reported.

Fever of less than three days' duration was the next most common complaint and occurred in at least one member of 30 families. Fever exceeding that length of time was reported five times.

Sunburn occurred in 10 families, and a non-specific rash was reported by 18 families. Bladder infection affected eight individuals. Respiratory symptoms were rarely reported and only two children had a cough lasting longer than three weeks.

Dental problems occurred in 26 individuals representing 17 (30 per cent) families. Heat prostration was rare; only four individuals were affected.

Injuries attributable to motor vehicle accidents were reported by five families; other accidental injuries occurred in 16 families (22 individuals), including seven cases of fractured bones and one moderately-severe burn. No respondent reported injury due to assault.

Parasitic infections were detected in 14 families (25 per cent) and 24 individuals. One worker acquired the lung fluke, *Paragonimus westermani*.

Depression was reported by eight families, and more often by the worker than by another family member. Boredom was reported by nine families and usually occurred in the wife. Anxiety was noted in 13 families and was reported equally for the worker and his spouse.

Other maladies included five cases of malaria, two cases of eye problems in children and one case each of hepatitis A and B infection. One spouse converted to positive tuberculin status. Hospitalization was reported in 13 individuals for the following reasons: childbirth (3), D & C (2), dehydration (1), kidney problem (1), malaria (2), pacemaker insertion [unnecessary procedure for previously known and stable sick sinus syndrome] (1), respiratory illness (1), perforated duodenal ulcer (complicated by peritoneal abscess and transfusion-associated chronic active hepatitis (second case of hepatitis B)) (1), back injury (1) and biopsy (1). Table 1 compares health experience by foreign-posting location.

**Table 1**

**Health Experience of Foreign-Posted Workers**

| Medical Problem | % of Families Affected | | | |
|---|---|---|---|---|
| | Ghana n=8 | Argentina n=13 | S. Korea n=29 | Pakistan n=6 |
| Diarrhea | 87.5 | 76.9 | 65.6 | 100.0 |
| Fever | 100.0 | 61.5 | 44.8 | 50.0 |
| Skin | 100.0 | 46.2 | 31.1 | 33.3 |
| Dental | 25.0 | 38.4 | 31.1 | 16.7 |
| Injury – MVA | 0 | 15.4 | 10.3 | 0 |
| Other Accident | 25.0 | 30.7 | 27.6 | 33.3 |
| Parasites | 37.5 | 15.4 | 20.7 | 33.3 |
| Depression | 12.5 | 0 | 24.1 | 16.7 |
| Anxiety | 25.0 | 15.4 | 31.1 | 0 |
| Hospitalization (excl. childbirth) | 25.0 | 7.7 | 20.7 | 0 |

## Prophylaxis and Preparation of Foreign-Posted Workers

Malaria chemoprophylaxis was necessary for workers in Ghana and Pakistan; seventy-five per cent and 83 per cent of workers respectively complied. Altogether, 73 per cent of families took a supply of drugs abroad with them; sixty-one per cent found these medications useful; a further 34 per cent found them somewhat useful. Travel advice received prior to departure was considered useful by 57 per cent of workers, somewhat useful by 34 per cent and not useful by nine per cent.

## Living Conditions Experienced by Foreign-Posted Workers

Table 2 lists foreign-posted worker ratings of medical and

**Table 2**

**Foreign Worker Posting Ratings**

| Subject | Rating % | | | |
|---|---|---|---|---|
| | Excellent | Good | Fair | Poor |
| Medical Care | 10.9 | 56.4 | 27.3 | 5.5 |
| Dental Care | 13.0 | 59.3 | 18.5 | 9.3 |
| Food Variety | 12.9 | 44.4 | 37.0 | 5.6 |
| Accommodation | 3.7 | 74.1 | 22.2 | 0.0 |

dental care, food variety and accommodation. Differences between foreign postings were noted with respect to accessibility to and quality of medical care. Seventy-five per cent of workers in Ghana rated medical care fair or poor compared to South Korea, where the medical care was rated good or excellent by 76 per cent of workers. In Argentina and Pakistan, 69 per cent and 83 per cent of workers respectively rated medical care good or excellent.

Accommodation was said to be infested by insects in 82 per cent of homes, by rodents in 50 per cent and by reptiles in 18 per cent (not mutually exclusive). Only 13 per cent of homes were not infested. Other creatures reported to be in and around accommodation were bats, horses, poisonous snakes and centipedes.

Workers were asked to indicate their level of alcohol consumption abroad compared to their pre-departure consumption. Alcohol consumption increased in 43 per cent of workers, remained the same in 54 per cent and decreased in three per cent. Two workers declined to respond. Table 3 compares life style factors between postings.

**Table 3**

**Life Style Factors Related to Foreign Postings**

| Life Style Factor | Families Responding Affirmatively %* | | | |
|---|---|---|---|---|
| | Ghana n=8 | Argentina n=13 | S. Korea n=29 | Pakistan n=6 |
| Clean water available | 38 | 84 | 24 | 17 |
| Safe food supply | 38 | 100 | 52 | 100 |
| Driving – safe | 25 | 39 | 38 | 17 |
| Dental care good/excellent | 20 | 92 | 86 | 83 |
| Alcohol consumption | | | | |
| – increase | 50 | 39 | 47 | 20 |
| – same | 50 | 61 | 50 | 60 |
| – decrease | 0 | 0 | 3 | 20 |
| Would go again | 100 | 92 | 79 | 100 |

* not all families answered every question

## Foreign-Posted Worker Recommendations

Workers were asked if they would take a foreign posting again if the opportunity arose: 87.5 per cent said they would, none said they would not and the remainder said they would with caution.

Table 4 lists foreign-posted worker advice to others.

**Table 4**

**Foreign Posting Worker Recommendations**

| Subject | Recommendation % | | |
|---|---|---|---|
| | Yes | No | With Caution |
| Other employees go | 87.5 | 0 | 12.5 |
| – with spouse | 90.7 | 0 | 9.3 |
| – with older children | 39.6 | 39.6 | 20.8 |
| – with small children | 76.3 | 5.5 | 18.2 |

## Comments by Foreign Workers

Respondents were given an opportunity to comment further upon their stay abroad, and more than half did. Most of the comments reflected favourably on the work experience. Negative comments referred to inadequate ambulance service, poor mail service, lack of meaningful work for spouse, inadequate schooling for adolescents and spoilage and irregular delivery of imported food. It was also commented that marital problems and learning disabilities had been exported overseas, that local management supervision was poor and that front-end preparation regarding medical advice and social changes could have been improved.

## Discussion

Despite evaluating only four foreign postings, these survey results likely pertain to other companies that send employees abroad. In general, the health experience of foreign-posted workers is favourable. Self-limited diarrhea is probably unavoidable during a prolonged stay in a rural area of an underdeveloped country. Malaria is a continuing menace to foreign workers, especially those who do not take appropriate chemoprophylaxis.

While these workers attended information meetings on their foreign postings in preparation for their assignment, the sessions were generally informal exchanges between people who had returned from the posting. Health advice pamphlets were distributed, but no formal disease

prevention presentations were made nor were there any discussions of cultural adaptation syndrome or psychosocial stresses of overseas residence.

Workers who accept foreign posting should make a totally informed decision. Front-end preparation should provide an extensive picture of living conditions at the assignment with a full and frank discussion about social interaction with other expatriates and nationals, recreation, cultural resources and daily problems of living. Handbook-type material that attempts to define what personnel in foreign postings need to know regarding personal health care in such settings is recommended to reinforce these discussions.

A family life pack of assorted medications should be part of every family's overseas luggage. As a minimum, it should contain: analgesic stronger than A.S.A.; antacid; antidiarrheal; antihistamine; skin antiseptic and antifungal; broad spectrum antibiotics; laxative; antimalarial (if required); Ana kit (if required); sufficient own prescribed medication; sunscreen; extra pair of glasses or lens; band aids, gauze, water treatment tablets, insect repellant and an oral thermometer.[5]

Living conditions for foreign workers are usually better than those of the surrounding population. However, water often has to be boiled to render it safe, and the food supply, both imported and domestic, is often of suspect quality. Overseas residence usually requires putting up with some insect, rodent and reptile infestation of accommodation. Driving is a hazard in the developing world, but personal safety may not be an issue depending upon posting location.

Medical and dental care vary between foreign postings, and drug availability may be the limiting factor for quality medical care in some lesser developed countries. Under some circumstances, therefore, a company may choose to provide its own medical services.[4]

Depression, boredom and anxiety occasionally occur among workers and their spouses. Careful pre-posting selection and family unit assessment may identify workers and families unsuited for foreign posting. Older adolescent accompaniment may not be desirable unless the posting provides adequate schooling and socio-recreational activities for teenagers.

Workers abroad have a tendency to increase their alcohol consumption wherever they are stationed. This should be investigated further with regards to job stress, availability of extra-occupational activities and cultural maladaptation syndrome.[5] Most workers, however, look

positively upon their overseas experience and would take another posting if the opportunity arose.

**Résumé**

Ce document décrit les manifestations ressenties, sur le plan santé, par un certain nombre de travailleurs revenant d'une affectation dans un pays étranger. Les symptômes les plus fréquents étaient la diarrhée et la fièvre évoluant spontanément vers la guérison en moins de trois jours. En outre, certains employés et leurs conjoints déclarent avoir souffert de dépression, ennui et anxiété. On a remarqué que les employés détachés à l'étranger avaient tendance à accroître leur consommation d'alcool. En outre, il a été établi que la conduite automobile dans les pays en voie de développement présentait des dangers certains. Ce document fait état des recommandations des travailleurs et des différences qui existent entre les diverses affectations.

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# Farming, Pesticides and Occupational Health*

## Summary

*Rates of occupational mortality and morbidity are increasing in the agricultural sector mainly because of the gradual replacement of human labour by machines and pesticides. The agricultural environment is not well suited to the safe management of pesticides, and frequent exposure of workers has been documented. Few severe acute poisonings are reported, however, and the greatest concern must centre around chronic effects. These are not well researched, but there is preliminary evidence that some pesticides could be carcinogenic and that farmers may have a higher incidence of certain types of cancer.*

*In order to decrease the occupational risks associated with agricultural pesticides it is necessary to improve handling practices,*

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## Introduction

Agriculture was defined by the Joint International Labour Organization/World Health Organization Committee on Occupational Health as: all forms of activities connected with the growing, harvesting and primary processing of all types of crops, the breeding, raising and caring for animals and tending gardens and nurseries.[1] In Canada this definition has been restricted legally[2] to exclude silviculture (the raising of trees) and, occasionally, horticulture (the raising and sale of garden products).

Agricultural workers are subject to a variety of occupational health and safety hazards, which, in several respects, are unique to their industry. The major problem areas are similar to those in other industries, i.e. physical trauma, often associated with the use of machinery, and exposure to toxic chemicals. Agricultural chemicals are unique, however, in that a large proportion of them are pesticides — chemicals that are formulated specifically to be toxic to living organisms. Other factors that make agricultural health and safety problems different from those of other industries are: outdoor work, occasionally under severe climatic conditions, long hours of labour necessitated by natural growing cycles, and exposure to infectious agents and dusts from soil, crops and animals.

More and more occupational health and safety problems have developed in the agricultural sector in recent years. This is mainly because of the gradual replacement of human labour by machines and pesticides, which has increased the contact between the farm worker and these potentially harmful items. Pesticide use has become more widespread for two reasons: like machines, they lessen the need for expensive manual labour; also, they improve the yield, quality, uniformity and cosmetic appearance of crops, and, therefore, increase profits. In addition, the popularity and profitability of covering large areas of land with pest prone stable monocultures has contributed to the greater use of pesticides.

Gathering data on health and safety in agriculture to

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*encourage the development and use of safer pesticides and decrease the total amount used without undue production losses. This can be accomplished by education, legislative change and co-operation between government and the agricultural sector. In particular, a global approach to pest control, such as Integrated Pest Management (IPM), which decreases dependence on pesticides, should be encouraged.*

support the above statements is very difficult. The reasons are many. Farming is one of the few human endeavours that is nearly pure private enterprise, with rugged independence from external factors and influences. Hired farm workers tend to be poorly educated; many do not speak English[3] and some may be illegal immigrants, thus, officially, non-persons. They are often itinerant and are usually not unionized or organized in any way. In Ontario and most other provinces farm workers are not covered under the *Labour Relations Act*[2] or the *Occupational Health and Safety Act*[4] and are covered under the *Workers' Compensation Act* only if there are paid workers at the worksite[5]. In Ontario approximately only one-third of farms are so covered.[6] In addition, the farm is a place of business as well as a place to live. Those who are there are not spending all their time at farm work, and many of the hours of work put in by family members and owner-farmers are uncounted and unpaid. Injuries and disease may seem to them to be a normal part of life rather than occupational in nature.

As mentioned previously, the definition of agriculture may vary from one data base to another, particularly with regard to the inclusion or exclusion of horticulture. For this and a host of other reasons there is a general lack of comparability between data sources such as Statistics Canada, the federal and provincial agriculture and labour authorities and semi-autonomous bodies such as workers' compensation boards and farm safety associations[7]. In addition to, or perhaps partially because of, the above problems, very little research has been done on agricultural health and safety. For example, of the approximately $19 million paid in Canadian federal public health research grants between 1965 and 1970, only $667,000 went to projects related to agricultural health.[8]

Thus it is very difficult to document the rates of death, injury and disease in agriculture. Dr. Earl Haslett was commissioned in 1983 by the Ontario Task Force on Health and Safety in Agriculture to determine the trends in health and safety in agriculture in Ontario. Despite considerable research, Dr. Haslett was forced to make a number of estimations and extrapolations in order to determine mortality and morbidity related to Ontario farming. His final conclusions are as follows.[7] Between 1961 and 1981:

1. the number of farmers decreased 32 per cent;
2. the total population living on farms decreased 45 per cent;

3. the agricultural labour inputs decreased 32 per cent;
4. farm output increased 52 per cent;
5. mechanization and chemical use were the two primary agents accomplishing this increase in output;
6. farm machinery was associated with 77 per cent of the accidental deaths that occurred on farm property (66 per cent with tractors alone);
7. the rate of fatalities occurring on farm property (exclusive of the house) per 100,000 farm population rose 56 per cent;
8. the rate of fatalities occurring on farm property (exclusive of the house) per 100,000 person years of farm labour rose 15 per cent;
9. it was not possible to develop a definite assessment of morbidity rates due to inadequate data;
10. data are inadequate to identify the population exposed or to count adverse health occurrences accurately.

In the United States a recent report from Texas[9] states that agriculture has the second highest rate of fatal occupational injuries. Farmers themselves were the eighth highest risk occupation with an occupational fatality rate two-and-one-half times the average rate. One-third of the agricultural deaths were due to machinery.

Strigini[10] estimated that, in the U.S., farm labour declined from 11 per cent of the labour force in 1950 to 2.5 per cent in 1978. Despite this, at the time his paper was written (1982), farm labour accounted for 15 per cent of the deaths and seven per cent of the disabling injuries among American workers. He put the death rate in third place, inferior only to that of construction workers and miners, and stated that the injury rate was the highest in all industry. Like Haslett, Strigini felt that these rates were inaccurate due to an inadequate data base and were probably underestimates.

The increasing use of mechanization and pesticides is easier to document accurately. Haslett[7] notes that the number of farm machines per 100 farm people increased in Ontario from 73 to 139 between 1961 and 1981. The Canadian Centre for Toxicology, in its report to the Ontario Task Force on Health and Safety in Agriculture,[11] reports that pesticide use in Ontario increased from 5.5 thousand metric tonnes in 1978 to 8.7 thousand metric tonnes in 1983, while the total area grown remained relatively constant. Strigini[10] states that pesticide use in

the U.S. increased by 207 per cent and fuel consumption (a measure of mechanization), by 62 per cent between 1969 and 1974.

## Pesticides

A pesticide has been defined[12] as any substance with the capability of destroying the life of some form of organism that is deemed to be undesirable. Pesticides include insecticides, herbicides, rodenticides, fungicides, molluscicides and nematodicides.

Pesticides are controlled in Canada by the *Pest Control Products Act*, which is administered by the Pesticides Division of Agriculture Canada.[13] After consultation with other ministries, such as Health and Welfare Canada, Environment Canada and other departments within Agriculture Canada, the Pesticides Division decides whether the evidence submitted by the manufacturer of a proposed pesticide demonstrates its safety and efficacy. If so, the pesticide is registered for use. Each province also has a pesticides act, which sets out regulations for the handling of each pesticide within the province. Individual provinces can restrict the use of pesticides approved by Agriculture Canada under this two-tiered system.

Pesticides are the focus of this article for the following reasons. They have been implicated above as one of the possible causes of increasing rates of occupational health and safety problems in the agricultural sector. They represent a significant proportion of the chemicals used on the farm and they present, by their very purpose, a potential health risk to the farming population. The other possible contributors to increasing rates of death, injury and disease on the farm (physical trauma and contact with toxic substances whose presence in the workplace is necessitated by properties other than their toxicity to living organisms) are common in many industries and thus are well known to those specializing in occupational health. In contrast, intense contact with pesticides represents a risk confined to farming and a few other occupations such as the pesticide manufacturing industry and forestry. The general population is, however, at some risk of exposure to pesticides, albeit less frequently and at lower concentrations than agricultural workers. Thus the health hazards due to these compounds on the farm are of interest to all health care workers and the general public.

Farming represents a worksite in which pesticides are likely to be handled in an unsafe fashion. Farmers must master multiple tasks in their day-to-day work and are unlikely to invest the time or effort required to become

expert in any of them, including pesticide use. In addition, both the sale of pesticides and their use on the farm are governed by the profit motive. Unfortunately, one way to make pesticide use cheaper is to neglect the costly training, storage, disposal and personal protective equipment needed to use them properly. The pesticide salesman, one of the farmer's contacts who could potentially help to educate him in pesticide use, is not likely to stress the need for these expensive items if it might mean the loss of a sale. Another problem is the fact that the farm workplace is out of doors, with uncontrollable climatic conditions. It is often isolated enough to make machinery and personal protective equipment difficult to obtain, repair and maintain properly. In addition, the farm worker is unprotected by all the major labour legislation, leaving the protection of his health up to the goodwill and expert knowledge of his employer, who may be wanting in both of these attributes. The fact that the farm is both a workplace and a home to farm families leaves many who are not normally considered to be workers, such as farm children, open to exposure. Contamination of the family's food and living quarters is much more likely because of their proximity to the worksite.

Two studies are available that emphasize these problems. The only Canadian study of farm workers' exposure to pesticides was carried out with federal funding in British Columbia in 1982.[3] After a random selection of farms representing various crops and farm sizes, a total of 272 farm workers from the Okanagan and Fraser Valleys were interviewed. A response rate of over 90 per cent was achieved. It was found that more than half of the workers reported having been directly sprayed by pesticides, and 25 per cent reported that their living quarters had been sprayed. Seventy per cent of those sprayed had become physically ill following the incident, but only three per cent of these received medical care. No proper washing facilities were available to 70 per cent of the workers, and 80 per cent had no choice but to eat lunch in sprayed field areas. A total of 88 per cent had been given no information or instruction on pesticide hazards. Any of these practices would be a clear infraction of occupational health and safety legislation if it applied to farm workers.

An American survey[14] of farmers using pesticides found that only 30 per cent had received formal instruction in pesticide handling and that 62 per cent felt

that safety equipment cost more than it was worth and had no safety equipment on hand. The survey also found that 50 per cent of the stores selling pesticides did not carry protective equipment. In order to assemble adequate personal protective equipment, the farmer would be required to shop in many different stores in the area, and, despite this, no adequate gloves could be obtained locally. These researchers commented that the farmers had a lack of understanding of the long-term hazards and cumulative effects of pesticides, which led them to display an offhand attitude to those pesticides that do not show any symptoms immediately after short-term exposure.

## Acute Toxicity of Pesticides

Documentation of the number of events attributed to acute pesticide toxicity is available. For example, The Canadian Centre for Toxicology[11] was able to document that 3,404 episodes of pesticide poisoning occurred in Canada in 1983, with 1,458 requiring medical care and two resulting in death. Both deaths were considered to be suicides and therefore cannot really be attributed to the pesticides that happened to be used. In the five years from 1979 to 1983 there were only seven deaths attributed to accidental pesticide poisoning. These statistics include all exposures, not just those associated with agricultural use. However, they are probably underestimates because of underreporting. For example, the British Columbia study mentioned previously[3] found that only a small fraction of the farm workers who become ill following pesticide exposure receive medical attention. The remainder are probably not reported. This low treatment and reporting rate is partially due to the lack of legislative protection of the agricultural worker.

Haslett[7] reports that 'chemical' injuries on farms accounted for an average of only five lost-time injuries per year reported to the Ontario Workers' Compensation Board. This accounts for only 0.2 per cent of all reported lost-time injuries on farms. There is probably a large degree of underreporting in these statistics as well because the Ontario Workers' Compensation Board data represent mainly hired farm workers, not farmers or unpaid farm labour.

Deaths, however, are probably not greatly under-reported. In Ontario, Haslett[7] counted an average of 20 deaths per year due to agricultural machinery, but failed to even make a category for pesticide deaths. Thus, when compared to other hazards in farm work, it must be

concluded that acute pesticide poisonings are probably not a major contributor to the problem of occupational safety and health on the farm, at least in Ontario, and this is probably true in most of the developed world.

The problem of acute pesticide poisoning may be much worse in developing countries. In Sri Lanka during 1977 for example, there were nearly 1,000 reported deaths due to acute pesticide poisoning. In contrast, during the same year, the total number of deaths reported due to polio, tetanus, diphtheria, whooping cough and malaria was only 649, far fewer than those due to pesticides.[15]

## Chronic Toxicity of Pesticides

All of the previously discussed causes of death, injury and disease in agriculture are acute and therefore easily seen and documented by the researcher who wishes to take the time and effort to do so. Chronic toxicity due to pesticides is much more insidious. Therefore, documenting it is much more difficult. Many years may elapse between exposure and outcome. By the time the outcome has occurred, the exposure may have been forgotten. In addition, many other confounding variables, including multiple exposures, may have entered the picture. Considering the previously discussed problems surrounding agricultural health and safety data, these additional problems make research into the chronic effects of pesticides in agriculture very difficult.

The possibility of chronic toxicity from some pesticides is very real, however, and worth pursuing despite the difficulties. Possible chronic effects include adverse reproductive outcomes, reduced fertility, functional abnormalities of various organ systems and cancer. Presumably because cancer is somewhat easier than the other outcomes to define and study and because it has such devastating health effects, some information concerning the relationship between cancer and chronic agricultural pesticide exposure is available and worth discussing.

*In vivo* cytogenetic testing has revealed the potential of at least 16 pesticides to induce chromosome abnormalities with or without mitotic aberrations – chromosome breakage, rearrangements, clumping, unwinding of chromosomes, endopolyploidy, anaphase and telophase bridges and tripolar or tetrapolar anaphases.[16] Pesticides with this potential have a very real possibility of being carcinogenic and have been further tested in animals. In addition, epidemiologic studies have been carried out to detect possible carcinogenesis in humans.

In summarizing the knowledge to date, the International Agency for Research on Cancer (IARC) stated in 1983 that there is limited evidence that two pesticide groups, the phenoxyacetic acids (e.g. 2,4-D, 2,4,5-T) and the chlorophenols (e.g. TCP, PCP) are carcinogenic in humans. In addition, 15 pesticides have shown some evidence of being carcinogenic in animals, possibly at very high doses, but there is inadequate evidence to evaluate their carcinogenicity in man. Only three pesticides are designated as having no evidence of cancer risk by this group.[17]

A large number of epidemiologic studies have looked at incidence or mortality rates for various malignant diseases among farmers. Most suffer from problems associated with the inaccuracies in the data base listed previously. In addition, most study populations (not individuals) and pesticide exposure is assumed, not documented. Pesticides include an enormous range of different chemicals with wide-ranging biological activity. They should not be lumped in one category, as is done in most studies. In addition, the pesticides used in the past by those now displaying malignant disease may differ from the ones now in use. Inevitably, even very recent cancer incidence data would be expected to show the effects of exposures that occurred 10 to 30 years ago.

Despite these difficulties, the following major patterns of malignant disease have been detected. Increased rates of leukemia (usually myeloid leukemia) have been found in farmers in Washington state,[18,19] California,[20] Iowa,[21,22] Wisconsin,[23] Nebraska,[24] Illinois,[25] North Carolina (blacks only)[26] and the U.S. in general.[27] Increased rates of various lymphomas have been found in farmers in Washington state,[19] Wisconsin (whites only),[30,31] California,[32] Iowa,[33,34] Illinois,[25] New Zealand[34] and the United Kingdom.[35] These two cancers both occur in the same organ system, and their increased incidence in farmers in such widely different geographical areas is noteworthy. The fact that increased leukemia rates were searched for but not found in North Carolina (whites only),[26] Minnesota[28] and Sweden[28] and the fact that increased lymphoma rates were not found in North Carolina[26] and the U.S. in general[36] does detract from the consistency of the results but is to be expected in light of the major differences in farming practices, pesticide use, other exposures in these different areas, such as smoking, and the great gaps in the data available for analysis.

A group of Swedish researchers have found a much higher incidence of an unusual lymphoma (soft tissue

sarcoma) in Swedish farmers and other workers exposed to the chlorophenols and phenoxyacetic acids.[37–39] An increase in this same form of cancer has been detected in some workers manufacturing these compounds[40–42] and Vietnam veterans who were exposed to them when using the defoliant known as Agent Orange.[43,44] It was the Swedish studies that prompted the IARC to state that there is limited evidence that these compounds are carcinogenic in humans.

The issue of the carcinogenicity of these compounds is far from resolved. Other studies of exposed workers[45,46] and Vietnam veterans[47,48] have shown no increased cancer incidence, and the Swedish studies have been criticized by such august bodies as the U.K. Pesticides Advisory Committee, the U.S. Environmental Protection Agency and Health and Welfare Canada.[49] All of the studies mentioned suffer from inadequate exposure information. The American military is, at present, carrying out some more definitive studies on their Vietnam veterans,[43] and the issue may be resolved once these studies are complete.

Meanwhile, policy decisions must be made. In 1983 the Nova Scotia Supreme Court was asked to weigh the merits of the evidence against a proposed spraying program involving 2,4-D and 2,4,5-T (the only legal case of its kind in North America). The judgement stated that, in the concentrations proposed, neither compound poses any health hazard whatever.[49] During the trial it was pointed out by a group of scientists that, since 15 per cent of the Swedish work force have been engaged in handling these pesticides for the past 35–40 years and the studies predict a sixfold increase in risk for soft tissue sarcoma in this group, one would expect an enormous increase in the incidence of the cancer in Sweden. The scientists found, instead, that there had been no overall increase in the Swedish rate for the cancer.

The evidence linking cancers at other sites to agricultural pesticide use is less noteworthy. Again, the studies suffer from the previously mentioned flaws of poor or absent exposure information, confounding variables and generally inadequate data. Increased rates of skin cancer and melanoma have been found in farmers,[23–26,31,33] but the relationship of this finding to pesticide use is unknown because the increased sun exposure of this group may be sufficient explanation. Increased rates of brain cancers have also been found in

some studies[19,26,50–52] but not in others.[22,29] Lung cancer has been found to be less frequent in farmers,[19–21,29] which may be due to significantly decreased tobacco use in this group.[53,54] One study of German agricultural workers whose smoking habits were the same as those of other Germans found an increase in lung cancer with a positive dose response.[55]

Another group of studies has looked at cancer rates in pesticide applicators. In general, these studies have much better exposure data, although multiple exposures is a problem, and often no attempt is made to even record the various pesticides used. One[56] detected significant increases in the rates of leukemia, CNS cancers and lung cancer and was able to show a dose response for the lung cancer without considering smoking habits. This finding for lung cancer contradicts the findings in farmers, except those in Germany, and highlights the tremendous confounding problems in these studies. Another study of pesticide applicators[57] showed a statistically significant increase for only bladder cancer.

Studies of workers occupationally exposed to pesticides in industry have generally not found any increase in cancer mortality,[58–60] with the exception of the previously mentioned industrial workers who were exposed to phenoxy herbicides and chlorinated phenols.[38–42] This may be due to extraneous factors such as lower exposures in the industrial setting, and may not constitute enough evidence to question the positive findings in farmers. In general, these studies have better exposure data and less problem with multiple exposures.

In conclusion, there is no definitive epidemiologic evidence linking pesticides to occupational cancer in farmers. There is enough evidence only to cause some concern and prompt further study. The evidence involving phenoxy herbicides and chlorinated phenols is the strongest, with specific documented exposure to specific chemicals linked retrospectively to a very rare form of cancer. The link also makes biological sense because these pesticides are known to be contaminated, like their cousins the polychlorinated biphenyls, by dioxins and furans, which have been implicated as carcinogens.[12] Despite this, as mentioned previously, the evidence linking these pesticides to cancer is highly controversial. These chemicals, which are heavily used (2,4-D is the 10th most heavily used pesticide in Ontario),[11] are also of concern because they have minimal acute toxicity to man, and, as pointed out previously, this leads to casual

handling and heavier exposure of farm workers and families.

## The Need for Pesticides

Since pesticides represent a potential for harm, it is reasonable to consider the necessity for using them. The pesticide manufacturing industry is firmly committed to the idea that modern agricultural practices, which have led to high yields and helped to feed a hungry world, would not be possible without pesticides. They feel that when properly used, pesticides can contribute to increased production, decreased costs, decreased losses during storage and control of vector-borne disease. In addition, herbicides specifically have allowed the development of the minimum tillage farming method, which contributes to the conservation of moisture in soil, saves energy and reduces soil erosion as well as allows mechanical harvesting. The hazards of pesticides are viewed as minimal and unproven except for acute toxicity, which is rare if adequate precautions are taken. They readily admit that one-third of the world's potential harvest has continued to be lost to pests despite a massive increase in the use of pesticides. They also admit that vector eradication programs have failed. However, the blame is placed on inadequate utilization of pesticides and/or poor organization and management of programs. The solution recommended by these people is more and better planned pesticide use, particularly in the underdeveloped world. Meanwhile, they consider their mandate to be the development of new pesticides that are non-toxic to non-target organisms and affect the ecosystem as little as possible. They view pesticides as ultimately no different from tilling the soil – the object is to influence nature in favour of the crop.

The opposite point of view is taken by a diverse group of people, sometimes known as 'environmentalists'. Their point of view was well expressed by D. Pimentel, a faculty member of the New York State College of Agriculture, in the peer reviewed journal Bioscience.[62] Pimentel feels that the fact that crop losses to pests have remained relatively stable over the last 30 years despite large increases in pesticide use may be due to ineffectiveness rather than inadequate utilization. Removal of one pest by pesticides often merely encourages a resistant pest to take over. He predicts that complete discontinuation of pesticide use would only

increase crop losses, expressed in dollar value, from the present 33 per cent to 42 per cent overall, although it would be much higher in some specific crops, such as fruit. This nine per cent increase in losses expressed in dollar value would be only five per cent if expressed in calorie value. These losses could be compensated for by curbing unnecessary losses that now routinely occur during harvesting, distribution and food preparation. Only large prospective crop studies can determine whether the theories of Dr. Pimentel or the pesticide manufacturers are correct, and these have yet to be done.

The social effect of pesticides, which is not addressed by either the pesticide manufacturers or Dr. Pimentel, deserves mention. Particularly in the underdeveloped world, the social unrest, unemployment and poverty that results from pesticides replacing human labour must be considered a negative aspect of pesticide use.

The opportunity for an unbiased assessment of the risks and benefits of pesticide use – based on present knowledge – was created when the Canadian Environmental Advisory Council commissioned Dr. Ross H. Hall to prepare a report on the use of pesticides in Canada for the Minister of the Environment. Dr. Hall concentrated his attention on the appropriateness of using toxic chemicals for the suppression of pests and mediated the dispute between the two opposing factions mentioned above.[63] He concluded that chemical pesticides impose an environmental and human health burden that cannot be adequately assessed. Imposition of unknown risks could be avoided or minimized by using a more sophisticated, multitechnique approach to pest control, called Integrated Pest Management (IPM). This involves biological control, changes in cultural practices and the introduction of specific pathogens to replace pesticides whenever possible, and it also reduces pesticide use without increasing crop losses. It would require close co-operation between all levels of government and the agricultural sector.

Dr. Hall also felt that, at the present time, pesticides are not adequately tested – particularly in the Canadian setting – before being approved for use in Canada, and therefore the Canadian registration procedure should be improved. One method of accomplishing this would be to increase the roles of Environment Canada and Health and Welfare Canada in the registration process. These suggestions probably represent the most reasonable approach at the present time.

## Conclusion

The problems in occupational health and safety in the agricultural sector are increasing, mainly due to increased mechanization and possibly also due to increased pesticide use. This has made agricultural work one of the most hazardous of all occupations. If pesticides contribute to this increasing hazard in the developed world, they probably do so more by their chronic effects than by their acute toxicity. Frequent exposure of agricultural workers to pesticides is well documented. Concern is focused particularly on chronic exposure to compounds that have little acute toxicity. This is because the lack of acute effects encourages a casual attitude, which may lead to increased exposure. The phenoxyacetic acid herbicides are a heavily used group of pesticides in this category that have been identified in some controversial studies as human carcinogens. There is also preliminary evidence that other pesticides could be carcinogens and that farmers may be more prone than other occupational groups to certain types of cancer.

Given these concerns, it is prudent to search for ways to decrease the agricultural worker's chronic exposure to pesticides. This can be accomplished in several ways. They include: increased education of farmers in the safe use of pesticides and their potential hazards; increased legislative protection of the farm worker; increased regulation of pesticide suppliers (for example, forcing them to supply appropriate protective equipment along with the pesticide); increased emphasis on the health effects of new pesticides before registration by naming either Health and Welfare Canada or Environment Canada (both ministries have a mandate to promote health) the official administrator of the *Pest Control Products Act* as a replacement for Agriculture Canada, a ministry with a mandate to increase agricultural output; and a strong co-operative effort among all levels of government, the agricultural sector and industry to promote a decrease in pesticide use.

A global approach to pest management, such as the IPM suggested by Dr. Hall, offers the greatest opportunity to decrease pesticide use without major losses in agricultural output. This is the ultimate method of protecting both the farm worker and society from the harmful effects of pesticides, but it will require a complete change in attitude for many in the agricultural sector who still view pesticides as the magic bullet that will solve all their pest problems.

**Résumé**

On assiste actuellement à une augmentation des taux de mortalité et de morbidité professionnelles dans le secteur de l'agriculture, due principalement à l'élimination progressive de la main-d'oeuvre en faveur des machines et des pesticides. Le milieu agricole se prête mal à l'emploi, sans risques, des pesticides et la fréquence des cas d'exposition des travailleurs agricoles n'est plus à prouver. On a, cependant, signalé peu d'empoisonnements graves et il serait judicieux de porter notre attention sur leurs effets chroniques. Ceux-ci ne font pas l'objet de recherches approfondies, mais il a déjà été établi que certains pesticides pourraient être cancérigènes et que les agriculteurs peuvent être plus fréquemment sujets à certaines formes de cancer.

Afin de réduire les risques professionnels associés aux pesticides agricoles, il est nécessaire d'améliorer les méthodes de manutention, de favoriser la mise au point et l'utilisation de pesticides moins dangereux et de réduire la quantité totale de pesticides utilisés, sans pertes excessives dans la production. Pour cela, il faut avoir recours à l'éducation, introduire des changements de législation et assurer la coopération entre le gouvernement et le secteur agricole. Il s'agira notamment d'encourager l'utilisation d'un système global de lutte contre les ennemis des cultures, comme par exemple les programmes de lutte intégrée contre les ennemis des cultures, qui permettent de réduire la dépendance vis-à-vis des pesticides.

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# Styrene Exposure in the Reinforced Plastics Industry in Ontario

**Summary**

*A survey for styrene exposure was carried out in 10 plants selected as representative of the fibreglass-reinforced plastics industry in Ontario. Of a total of 628 employees, up to 130 (21 per cent) were exposed to styrene. The exposure during yacht fabrication is much greater than for other processes. The geometric means of samples obtained from plants in the marine sector ranged from 76 to 123 ppm and up to 151 ppm in the other sectors; the current short-term exposure limit of 100 ppm was exceeded in at least 48 per cent of the personal samples obtained from boat plants and 30 per cent of samples from non-boat plants. Industry-wide, about 70 per cent of*

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Styrene is used extensively in the manufacture of plastics and rubber products. Canadian demand in 1980 was approximately 200,000 tonnes,[1] the majority being used for polystyrene resins (59 per cent), styrene/butadiene rubber and latex (26 per cent) and acrylonitrile/butadiene/styrene/resins (12 per cent); the remainder (four to five per cent) was used in the manufacture of unsaturated polyester (alkyd) resins for paints and fibreglass-reinforced plastics (FRP). Over half the Canadian demand was consumed in Ontario, and it was estimated that approximately 5,400 Ontario workers in 400 plants were exposed to styrene during its manufacture and use,[2] with about 1,000 in the FRP industry. Occupational exposure to styrene has been reported[3] to result in a number of health problems, including central nervous system depression, haematologic abnormalities, respiratory symptomatology, reproductive and mutagenic toxicity, mucous membrane irritation and dermatitis.

Styrene monomer and polymer manufacture is carried out in closed systems, and exposure is consequently low, usually less than 10 ppm.[3] In the FRP industry, however, the processes are not generally enclosed, and exposures tend to be significantly higher. A number of studies[3] have focused on various aspects of exposure in the FRP industry; this paper reports the results of a survey of worker exposure to styrene carried out by the University of Western Ontario Occupational Health and Safety Resource Centre for the Ontario Ministry of Labour in 1981.

## Polyester Resins

A polyester (or alkyd) resin is a solution of a linear polymer in a liquid monomer that is capable of copolymerizing with the linear polymer. The linear polymer is derived from the esterification of a polyfunctional hydroxylic compound (usually a glycol) and an unsaturated carboxylic acid or anhydride; the reactive cross-linking monomer is usually styrene, which also serves as a diluent for the syrupy resin. Typically,

*personal samples exceeded a value of 50 ppm. The use of respiratory protective equipment was minimal. The sources of styrene exposure and the effectiveness of control measures throughout the industry are discussed.*

the styrene content of the raw resin is about 40 per cent by weight.[4,5] The blend of ingredients determines the properties of the final resin.

An inhibitor, such as hydroquinone or tertiary butyl catechol, is present in the resin to prevent premature reaction, and, in order to activate the resin, a catalyst is added before use. The catalysts are usually organic peroxides, the most common in the FRP industry being benzoyl peroxide and 'methyl ethyl ketone peroxide' (MEKP). The peroxides are shock-sensitive and highly unstable when heated and are diluted to 60 per cent with inactive solvents, such as dimethylphthalate (for MEKP) and dicyclohexylphthalate (for benzoyl peroxide).

## Fabrication Methods

Fabrication involves a number of procedures, both manual and mechanical, and these methods are described below. The spray-up method consists of spraying a mixture of chopped fibreglass, resin and hardener onto the surface of a mould. Continuous strands of fibreglass 'roving' are chopped into short lengths and carried by a stream of compressed air to be mixed with resin. The deposited mixture, in which the glass reinforcement is randomly oriented, is rolled out to extract air and allowed to harden. The glass content of this material is about 30 per cent by weight. Hand lay-up involves the manual lamination of resin-saturated chopped glass mat or woven glass fibre in an open mould, and the glass content is about 50 per cent by weight.

Filament winding is used in the construction of tanks and pipes. A tape consisting of many continuous glass strands inpregnated in a bath of resin (on a movable carriage) is wound onto a rotating mould (mandrel) while the carriage traverses the length of the mould. The required thickness is achieved by repeated cycles of coverage, and, typically, the glass content is between 65 and 75 per cent.[6] Rib winding is similar to filament winding except that strengthening ribs are built up by restricting the bath and carriage traverse to only a few inches.

The advantages inherent in spray-up are the complete wetting of the fibreglass reinforcement and faster production cycles.[7] Requirements for spray-up are less stringent than for hand lay-up, but uniformity in the product is not as reliable, nor as closely controlled, compared with hand lay-up processes. The hand lay-up method is preferred for the construction of large, complex parts where quality control is paramount, e.g. yacht

fabrication; the obvious disadvantages of hand lay-up are that production is labour-intensive. Hand lay-up, however, does lend itself to the fabrication of unconventional components. Specialized processes, such as yacht manufacture, can involve both spray-up and hand lamination.

It has been estimated[4,5] that about 10 per cent of the styrene content of resins evaporates during curing, and since a spray aerosol produces a larger surface area for evaporation than does a continuous film, spray-up operations may provide the most significant contribution to styrene contamination in FRP plants.

## Methods of Investigation

### Selection

The 10 plants comprising this study were selected by the Ontario Ministry of Labour as representative of current technology and as a reflection of the approximate market composition of the industry. Thus, four plants were chosen from the marine sector, two from recreational and consumer goods and one plant each from corrosion, construction, custom-moulding and coatings products. In accordance with the project specifications, information was collected regarding the products manufactured, quantities of materials used, employee exposure and control measures.

### Sampling

Attention was directed to personal exposure of the employees and also to the contributions from individual processes. The sampling strategy adopted was to place equal emphasis on all of the various operations in order to obtain a comprehensive view of exposures within particular job categories. Since the number of employees in a particular category was generally less than 12, personal samples were obtained from almost every individual according to NIOSH sampling criteria.[8] This sampling strategy would include 'maximum-risk' employees.

The current occupational exposure guideline[9] addresses both short-term (15-minute) and time-weighted-average (eight-hour) exposures. The results from long-term sampling may be quite variable owing to production volume, work regimen and administrative controls; furthermore, they provide no information on short-term exposures, which, according to the previous literature,[3] can significantly exceed current guidelines. Measurements

based on individual processes provide data on work practices independent of administrative controls and, hence, allow comprehensive assessments for individual plants. For the purpose of this study, it was decided to focus on exposure during particular operations.

Periods of approximately 25 minutes were taken for personal samples, representing the average of two sequential short-term samples; in some cases, further samples were taken. It is recognized that this sampling procedure may have underestimated the magnitude of short-term (15-minute) exposures and tended to overestimate eight-hour TWA exposure levels, although it will be shown later that results comparable with TWAs were obtained. Within the constraints of time and resources, this combined approach to sampling strategy was adopted.

Approximately one-third of the total number of samples were taken on a fixed-area basis. These samples were collected over periods ranging from five to 25 minutes. The volume of all air samples taken was five litres. The samples were collected on adsorption tubes (SKC Inc.), which contained 150 mg of activated charcoal, using Bendix C115 (low flowrate) and Dupont P2500 pumps calibrated before and after use. Samples were analysed for styrene by the NIOSH S30 method, using a Tracor 560 gas chromatograph with a flame ionization detector, 10 per cent FFAP on 80/100-mesh acid-washed DMCS Chromosorb W in a 10 ft. x 1/8 in. ID stainless-steel column. Chromatograms were obtained, using a Linear Model 252A chart recorder with an electronic integrator. Samples were injected into the gas chromatograph, using the flush-injection technique to minimize blowback or distillation within the syringe. Sample injections were repeated until the reproducibility of results was within three per cent. The retention time for styrene was 3.17 minutes; average desorption efficiency was 0.85, with a coefficient of variation of 0.065. As an additional quality control measure, one-third of all samples taken were replicates forwarded to the Ministry of Labour for independent analysis. Irrespective of the flowrate used, breakthrough was within acceptable limits.

Air pressure was measured with a surveying aneroid barometer (T. Wheeler), with an accuracy of $\pm 0.05$ kPa; temperature measurements had an accuracy of $\pm 0.05$°C.

## Results

Sampling was carried out during February and March 1981. Inside temperatures ranged from 17.6° to 21.4°C in yacht plants and from 14.1° to 25°C in the others; the

corresponding barometric pressure ranges were 101.3 – 104.3 kPa and 100.2 – 102.1 kPa. The airborne styrene concentrations could, for the purpose of comparison, be corrected to arbitrary standard conditions (say, 20°C and 101.3 kPa), but the values would be altered by about two to four per cent only; this difference is not significant, and, hence, corrections for temperature and pressure have not been applied. About 130 out of a total of 630 employees (i.e. 21 per cent) were acutally exposed to styrene. Tables 1 and 2 summarize plant information.

**Table 1** **Plant Information**

| Plant No. | Product | Employees Total | Employees Total Exposed | Resin Use ($10^6$lbs/yr) | Plant Area ($10^3$sq.ft) | Ventilation (Local) |
|---|---|---|---|---|---|---|
| 1 | Continuous Sheet | 50 | 8-10 | 1.0-1.5 | 15 | S |
| 2 | Pipe | 44 | 20-25 | 1.0-1.5 | 30 | S |
| 3 | Recreational Equipment | 18 | 8-9 | 0.20.3 | 8 | B |
| 4 | Recreational Equipment | 45 | 4 | 0.1 | 0.3 | C,S |
| 5 | Miscellaneous | 3 | 2-3 | 0.01 | 1.8 | B |
| 6 | Gel-Coat | 120 | 4 | 1.0 | 1 | S |
| 7 | Boats | 50-52 | 18 | 0.3 | 8 | B |
| 8 | Boats | 230 | 40 | 1.0 | 12 | B |
| 9 | Boats | 30 | 10 | 0.08 | 2.4 | B |
| 10 | Boats | 36 | 6.7 | 0.2 | 4.5 | B |
| | Totals | 628 | 120-130 | | | |

B – Booth
C – Canopy
S – Slot

**Table 2** **Styrene Concentration by Plant Category**

| Category | Resin Use $10^6$ lbs/yr | Mean Styrene Conc. (ppm) | Plant Nos. | Employees Exposed |
|---|---|---|---|---|
| I Small Non-Boat | 0.01 | <50 | 5,6[a] | <5 |
| II Small Boat Non-Boat, large area | 0.1-0.3 | 50-100 | 1[b],3,7,9,10 | approx. 10 |
| III Large Boat; | 1.0-1.5 | >100 | 2,4[c],8 | >10 |

[a] High resin use. Process enclosed
[b] High resin use. Process semi-enclosed
[c] Medium resin use. Constricted area (2 employees)

Sampling data are shown in Tables 3 and 4, with styrene exposures according to job classification in Table 5. The results for personal samples are depicted graphically in conventional log-probability plots (Figure 1); the data points correspond to the range delineations given in Tables 4 and 5. In Figure 1 are shown the cumulative distribution frequencies for personal samples from the marine and other sectors, together with the results derived from a study[10] of exposure in the marine sector of the FRP industry in the state of Washington, U.S.A.

The results for laminators had a geometric mean of 89 ppm and a geometric standard deviation (GSD) of 2.06,

**Table 3**

**Employee Information and Mean Styrene Concentrations**

| Plant Number | Employees Sampled | # Samples[a] | Styrene Concentration, ppm Range | Geom. Mean | Arith. Mean |
|---|---|---|---|---|---|
| 1 | 8 | 12(9) | 16-127 | 58 | 70 |
| 2[b] | 7 | 10(4) | 10-103 | 27 | 34 |
| 2[c] | 6 | 10(6) | 82-316 | 151 | 168 |
| 3 | 8 | 11(4) | 15-154 | 70 | 82 |
| 4 | 3 | 4(5) | 105-184 | 139 | 107 |
| 5 | 2 | 4(4) | <1 | <1 | <1 |
| 6 | 4 | 9(6) | 1-36 | 9 | 15 |
| 7 | 9 | 12(8) | 48-193 | 76 | 87 |
| 8 | 16 | 21(5) | 28-327 | 118 | 147 |
| 8[d] | 9 | 14(5) | 78-322 | 123 | 140 |
| 9 | 8 | 12(5) | 29-238 | 96 | 103 |
| 10 | 5 | 7(4) | 59-113 | 83 | 85 |
| Totals | 85 | 126(65) | | | |

[a] Area samples in parentheses
[b] Rib winding in progress
[c] Filament winding in progress
[d] Night shift

**Table 4**

**Styrene Distribution* by Plant Type**

| Plant Type | Concentration Range (ppm) <25 | 25-50 | 50-100 | 100-150 | 150-200 | 200-250 | 250-300 | >300 | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Boat | 0(8) | 9(5) | 25(7) | 16(4) | 4(2) | 6(1) | 3(0) | 3(0) | 66(27) |
| Non-Boat | 21(17) | 9(7) | 12(4) | 12(6) | 3(3) | 1(0) | 0(0) | 2(1) | 60(38) |
| Totals | 21(25) | 18(12) | 37(11) | 28(10) | 7(5) | 7(1) | 3(0) | 5(1) | 126(65) |

* Personal samples; area samples in parentheses

**Table 5** **Styrene Concentrations by Job Classifications (Personal Samples)**

| Job Classification | Concentration Range (ppm) 0-50 | 50-100 | 100-150 | 150-200 | 200-250 | 250-300 | >300 | Totals |
|---|---|---|---|---|---|---|---|---|
| Lamination | 17 | 28 | 19 | 6 | 5 | 3 | 4 | 82 |
| Chopper Gun | – | 2 | 3 | – | 2 | – | 1 | 8 |
| Gel-Coating | 3 | – | 3 | – | – | – | – | 6 |
| Gel-Coat Mixing | 13 | 6 | 2 | – | – | – | – | 21 |
| Rib & Filament Winding | 6 | 1 | 1 | 1 | – | – | – | 9 |
| Totals | 39 | 37 | 28 | 7 | 7 | 3 | 5 | 126 |

**Table 6** **Styrene Concentrations by Plant Type and Job Category**

| Plant/Category | # Samples | Styrene, ppm GSD[a] | Geom. Mean[a] | Maximum Value |
|---|---|---|---|---|
| Boat[b] | 98 | 2.31(2.59) | 79(87) | 327 |
| Non-Boat[b] | 93 | 5.13(1.87) | 28(75) | 355 |
| Boat/Laminators | 59 | 1.90(2.18) | 101(108) | 327 |
| Non-Boat/ Laminators | 23 | 6.88(1.72) | 29(93) | 316 |
| Chopper Gun | 8 | 1.77(2.35) | 130(115) | 316 |
| Gel-Coat Spraying | 6 | 1.82(2.93) | 70(58) | 135 |
| Filament Winding | 3 | 1.41 | 125 | 181 |
| Rib Winding | 6 | 1.76 | 27 | 48 |
| Other[c,d] | 21 | 3.62 | 27 | 127[d] |

[a] Values in parentheses derived from full-shift sampling (Ref.10)
[b] Personal and area samples
[c] Gel-coat manufacture
[d] Continous-sheet manufacture

which corresponded fairly closely to that for boat laminators (see Table 6, geometric mean: 101 ppm; GSD: 1.90); the majority of the data – 59 out of 82 samples – were obtained from boat plants. Personal data for laminators in non-boat plants have a wide dispersion (calculated GSD: 6.88), and the parameters calculated for the results industry-wide are 71 ppm for the geometric mean and 3.28 for the GSD.

The geometric mean values and GSDs for the various

**Table 7** **Overexposure in Personal Samples**

| | Overexposure, % | | |
|---|---|---|---|
| | Boat Plants | Other Plants | Industry-Wide |
| 100 ppm Level | 48 | 30 | 40 |
| 50 ppm Level | 86 | 50 | 69 |
| 25 ppm Level | 100 | 65 | 83 |

operations are compared in Table 6, with those derived from the Washington state study. The percentage of samples indicating overexposure for various exposure criteria are shown in Table 7.

## Discussion

Occupational exposure to styrene depends on the proximity of the worker to a surface from which styrene is evaporating. The amount of styrene evolved is dependent on the extent of the surface area being fabricated, thickness of laminate, ratio of resin to reinforcement, temperature and the duration of each step in the process. It is often considered that summertime presents the least adverse conditions for worker exposure. Doors and windows are generally opened wherever possible, and, hence, infiltration is extensive. Implicitly, the overall ventilation tends to be at a maximum. However, worker exposure close to the point of contaminant generation may be subject to local influence from increased styrene evaporation, rather than its removal by enhanced ventilation overall. It should also be noted that the vapour pressure of styrene is markedly affected by temperature, doubling for a rise in temperature of 13 centigrade degrees. It is likely, therefore, that the relatively higher ambient temperatures in summer may give rise to higher styrene concentrations in plants with little temperature control. In this context, it may be noted that a number of employees in the FRP industry also provided subjective comments that the odour of styrene appeared to be much stronger in summer than in winter.

The plants in this survey may be categorized according to where the mean styrene levels were in relation to arbitrary levels of 50 ppm and 100 ppm (see Table 2). These delineations correspond broadly with the amount of resin used. Custom-moulding establishments tended to have low ambient styrene levels owing to the small number of employees and low resin usage; also, since these shops generally had paint booths – where gel-coating and chopper-gun spray-up were carried out –

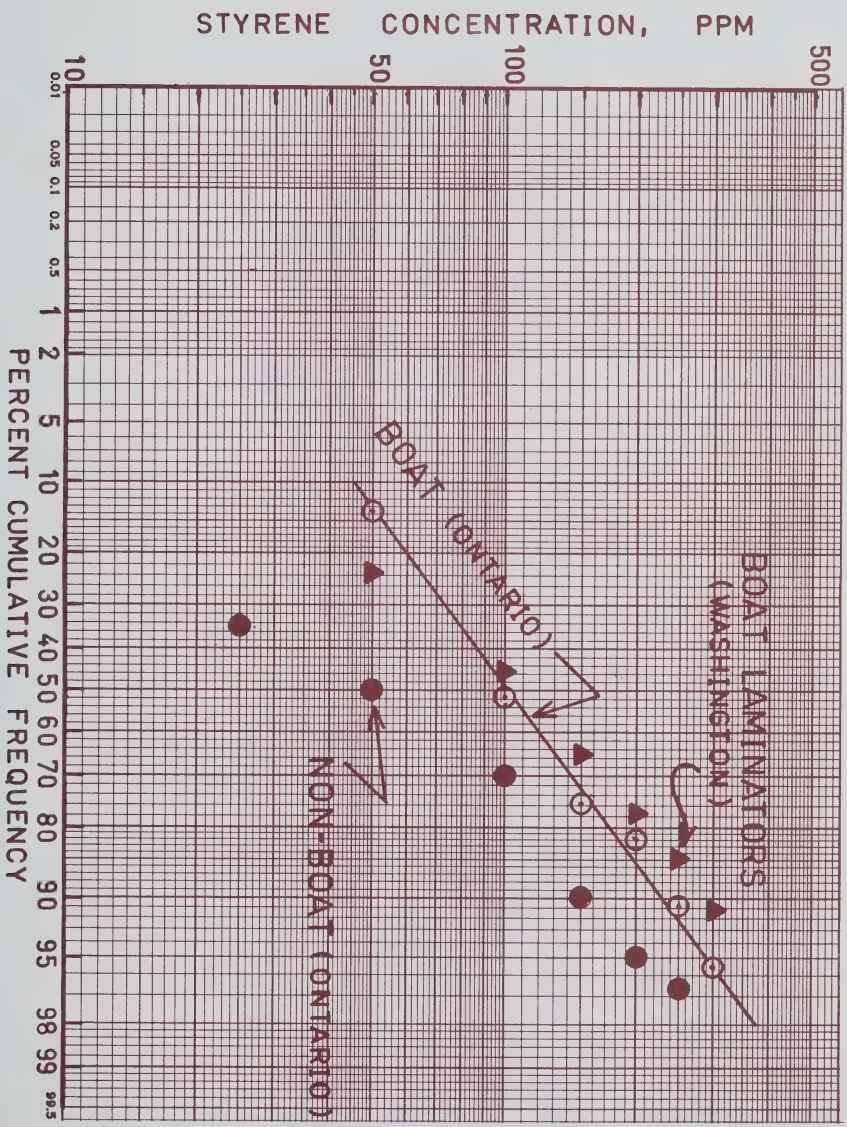
significant styrene emissions were largely isolated from the rest of the plant. Other plants with high resin usage sometimes had low styrene levels and exposure when the processes were enclosed (or well ventilated) as, for example, in the gel-coat formulation and mixing batch operations at Plant No. 6. Large plants, with resin usage in excess of $10^6$ lbs/yr involving large surface areas being fabricated, generally had mean styrene levels above 100 ppm. Plants with medium-sized operations tended to group in a category (50-100 ppm average) between the two extremes. Broadly stated, the results indicated that eight out of 10 plants had mean values above the current Ontario guideline of 50 ppm.

Plants from non-marine sectors were chosen for their diversity; however, the processes appeared to be so diverse, in fact, that it was difficult to categorize them systematically. As evident in Figure 1, the data did not follow a lognormal distribution and showed very wide dispersions: the geometric standard deviations (GSD) for all samples and laminators were 5.13 and 6.88 respectively (see Table 6). The contrast between the results for non-boat plants in Ontario and Washington state[10] also reflected the diversity of operations in these sectors; in the latter case, the uniformity of data may have been more apparent than real since the smaller establishments were omitted from that study.

By contrast, the results for the marine sector (yacht fabrication) showed consistency in that the results from both studies followed a well-defined lognormal distribution (Figure 1). As shown in Table 6 and Figure 1, the results from both studies were generally similar. Had the differences been larger, the higher values for the Washington state study might have been explained in terms of bias resulting from the exclusion of small plants. However, in the two studies, close correspondence was evident between the results for the individual operations of chopper-gun usage, gel-coat spraying and lamination. These similarities obtained even though the sampling durations in the present study were from one to three 25-minute periods and full-shifts sampling was adopted in the Washington state study. It was also noted that full-shift sampling data from contemporary Finnish,[11] British[12] and American[13] studies yielded essentially similar results. By implication it appeared that the present results were comparable with contemporary data and also provide a reasonable approximation for time-weighted average concentrations.

Individual samples showed a wide range of values.

**Figure 1** **Log-Probability Plots for Personal Samples**



During lamination and spraying, values in excess of 200 ppm were common (Tables 4,5) and three to four per cent of samples exceeded 300 ppm; these results appeared to be typical of the industry where effective local exhaust ventilation was difficult to achieve, most particularly in yacht manufacture. Maximum values in excess of 700 ppm have been reported[3] in the literature. During the present survey, instances of employees collapsing while working in confined areas were recounted; high short-term styrene levels are, perhaps, not surprising since the saturated vapour concentration of styrene is of the order of 10,000 ppm at 25°C. The use of the chopper-gun produced styrene levels up to 316 ppm. Chopper-guns, it was observed, were generally operated without local ventilation and, in this situation, exposure from spray-back and local accumulation would be possible. Where spray-up and lamination were carried out together, exposures for the attendant laminators were comparable. In the interests of quality control, gel-coat spraying was usually carried out in spray booths. The results showed that the exposure of gel-coat sprayers was about half that of chopper-gun operators, an indication that personal exposures during spray-up could be reduced by a combination of local exhaust (booth) ventilation and good work practices such as working 'upwind'. Where large surface areas were exposed, e.g. in the fabrication of large-diameter pipes (see filament winding, Plant No. 4), the styrene levels were comparable to those produced during use of the chopper-gun; by contrast, the exposure during rib winding was much lower.

For the FRP industry, curing is generally carried out at room temperature, but specialized processes may require higher temperatures. At Plant No. 1 the cure oven for the continuous sheet operates at 95 to 115°C and the preceding impregnation table is maintained at 38°C. The impregnation table exposes a considerable area (12 ft. x 6 ft.), and since the vapour pressure of styrene at 38°C is approximately twice that at room temperature, this open portion of the process represents the prime source of airborne contamination in the plant.

## Ventilation Controls

Virtually all plants, except the very small, have dilution (general) ventilation, and control of contaminant vapours is achieved by introducing large volumes of fresh air into the plant to generate turbulent air that is then exhausted through peripheral vents. The disadvantages of this type of control are high heating costs in winter and incomplete

mixing of air in the plant; if the local air movement resulting from remote addition and exhaust is slight, then local contaminant concentrations are only altered marginally. By the use of auxiliary fans, more rapid air movement and more efficient mixing is achieved. It has been claimed that this type of control is quite effective in reducing the levels of styrene in the breathing zone.[10,11] The disadvantage of this approach is that without control at source, contaminants are disseminated throughout the whole area and all workers are then exposed to low levels of styrene.

Spray-up constitutes a major source of airborne contamination in plants, and confinement within booths seems to be the appropriate means of engineering control.[13] The effect of this control was exemplified by the reduction in personal exposure levels of gel-coaters compared with chopper-gun operators as shown in the present study (cf. Table 6), and the same trend has also been noted in the Washington state study.[10] Although most yacht plants and custom-moulding establishments had spray booths, these were used mainly for gel-coating and painting; chopper-guns were most often used outside the booths for convenience.

Batch operations such as gel-coating mixing and milling (Plant No. 6) were amenable to local exhaust ventilation, and exposures were consequently found to be low. Although personal exposures during hand lay-up of small parts may exceed 100 ppm,[13] local ventilation was rarely seen to be applied. The sole exception in the present survey was at Plant No. 4 (recreational products), where side-draught and canopy hood exhaust ventilation were provided at slicking tables (where excess resin is brushed off), and canopy hoods were provided above impregnation troughs. In practice, employees leaned over the slicking tables and hence canopy hoods tended to draw styrene through the workers' breathing zone; furthermore, the table was too wide for the side-draught hood to provide effective ventilation. Consequently, personal exposures were high (105 to 181 ppm) during lay-up at this plant.

At Plant No. 1 the heated impregnation table was uncovered, but the raised edges incorporated a perforated-slot exhaust system; this side-draught ventilation would operate against convection and did not appear to be effective in controlling emissions from the 6 ft.-wide strip. Although a canopy hood above the table would be considered an appropriate means of control, its use had been tried and discontinued owing to the restriction of

access for frequent operational maintenance and quality control. Whatever the difficulties, the heated impregnation tables and resin outlets were the most significant source of styrene contamination in the plant. Area samples indicated levels of 121-184 ppm near walls where air circulation was impeded. Personal exposures were also high, up to 127 ppm.

Slot exhausts were provided at Plant No. 2 during the fabrication of large (6 ft.-diameter) shells. Three units were located in the area, each of 10,000 cfm capacity, with inlet slots positioned at floor level and at a height of about 5 ft. Since area and personal samples showed values up to 150 ppm and concentrations of 210 ppm during chopper spraying and 115 ppm during tank lamination (rolling), the local ventilation did not appear to be effective. The provision of local exhaust at floor level seemed to be based on the supposition (widely held throughout the industry) that styrene vapour is heavier than air and accumulates naturally at floor level. Although the specific gravity of styrene relative to air is 3.61, the effective specific gravity of the air-styrene admixture at saturation (about 10,000 ppm) is 1.026 and only 1.0003 at a concentration of 100 ppm; the effect of the density of the vapour is therefore insignificant relative to the influences of convection and general air turbulence.[14] The resin aerosol produced during spray-up is, however, heavier than air, and styrene may continue to evaporate from the surface of the droplets as they fall under gravity to floor level.

Yacht manufacture, particularly hull and deck lamination, poses special problems due to the size of objects and the difficulty in providing adequate ventilation. The use of auxiliary fans, either stationary or oscillatory, to facilitate mixing of air has been noted.[10,11] Push-pull ventilation at the bow and stern respectively is reportedly capable of reducing the personal exposures of laminators inside the hull to about 30 ppm[15] with maxima up to 97 ppm and with little spill-over. Even lower concentrations were reported in the same study where a tiltable hull was used in conjunction with make-up air introduced from above and drawn towards exhaust slots at floor level. In the boat plants that were included in the present study, it was observed that the use of local exhaust ventilation during hull and deck lamination was minimal.

## Work Practices and Other Controls

In view of the wide differences in styrene levels resulting from the various operations in the FRP industry, the effectiveness of administrative controls in reducing personal exposures is obvious. Common-sense work practices[16] relating to the minimization of exposure while spraying or directly handling resins, good housekeeping and effective use of spray booths have been shown to reduce significantly the styrene exposure in laminators. Low-styrene-emission (LSE) resins, which reduce styrene emissions as much as 95 per cent without inhibiting interlaminar adhesion have been reported;[17] little use was observed of such resins in the study reported here.

## Personal Protective Equipment

Inhalation is the major route of entry of styrene into the body. Despite high styrene levels, the wearing of respirators approved for organic vapours appeared, from observations during this study, to be the exception rather than the rule. More surprisingly, single-use dust respirators were frequently used, although they provided no protection against styrene vapour; this practice appeared to be quite prevalent in the industry[10] and reflected a considerable lack of knowledge among management personnel and workers alike.

High styrene concentrations are produced during spray-up and also during the lamination of large surface areas. It is considered that respiratory protective equipment approved for organic vapours should be worn by employees in close proximity to such operations. For hand lay-up of small articles, respiratory protective equipment would generally be unnecessary.

Most employees involved in hand lamination appeared to be indifferent towards personal protective equipment; quite a number exposed bare hands to the liquid resin, although some wore gloves or barrier cream. Despite conflicting reports, skin absorption does not appear to be a significant route of entry into the body for styrene,[18,19] although skin protection is generally recommended owing to the possibility of dermatitis.

## Occupational Exposure Standards

Various standards for styrene exposure are in force throughout Western countries, ranging from the OSHA (1969) value of 100 ppm TWA to the Swedish value of 25 ppm TWA. In Ontario the ACGIH value of 50 ppm

TWA with a short-term exposure limit of 100 ppm is currently adopted. In the present study 86 per cent of the personal samples taken in boat plants and half of the samples taken in other plants exceeded the value of 50 ppm. As well, since the sampling times were more than 15 minutes for personal samples, the results at the 100 ppm level present a conservative estimate for over-exposure at the current STEL level. Approximately half of the samples taken in boat plants exceeded the current STEL, as did about one-third of the samples from other plants. Expressed in other terms, the short-term exposure limit for styrene was exceeded in all yacht plants and in two-thirds of other plants.

The continued trend towards lower exposure limits would realistically have to be contingent upon control technology being available. It is improbable that the yacht-manufacturing industry is in compliance with current guidelines; the fact that hull laminators are in close proximity to large exposed surface areas without even rudimentary local exhaust makes it unlikely. Without personal protective equipment, it is considered unlikely that personal exposures would be reduced below 25 ppm.

It appears to be the Scandinavian experience[3,11] that levels lower than those found in the Ontario FRP industry can be achieved through a combination of high-volume low-velocity air movement, different plant layouts, proper work practices and low-styrene-emission resins; in the U.S.A. push-pull ventilation systems using stationary or oscillatory fans have been shown to be effective during boat manufacture.[10,16]

## Conclusions

Boat laminators are exposed to much higher styrene levels than are laminators from other sectors because of the large surface areas involved. Spray-up operations, which include the use of chopper-guns and gel-coat spray guns, represent the most significant source of airborne contamination in the plants. Little use is made of local exhaust ventilation during chopper-gun operations, and personal exposures are approximately twice those produced during gel-coat spraying, which is usually carried out in spray booths.

Engineering controls throughout the industry rely largely on dilution ventilation, but the measures taken are generally seen to be inadequate, more so in boat plants than in others. In this survey the current short-term exposure limit of 100 ppm for styrene was exceeded in all four yacht-fabrication plants and in four out of the six

remaining plants in the other sectors. The fabrication of large articles such as yachts or pipes is generally not isolated; the normal methods of design for exhaust ventilation are difficult to implement, and the industry faces problems in that connection. With improved work practices, a slight reduction in personal exposures is demonstrable, but significant reductions are probably only achievable through major changes to ventilation systems.

Styrene levels in excess of 300 ppm can be produced during, and in the immediate vicinity of, spray-up operations; although respiratory protective equipment should be worn in such situations, its use in practice is minimal.

**Acknowledgements**

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**Résumé**

Une étude sur l'exposition au styrène vient d'être menée dans 10 usines choisies comme étant représentatives de l'industrie ontarienne des plastiques renforcés à la fibre de verre. Sur un total de 628 employés, 130 (soit 21 %) étaient exposés au styrène. L'exposition à ce produit est sensiblement plus marquée dans la fabrication des yachts que dans les autres utilisations. Les moyennes géométriques des échantillons prélevés dans les usines du secteur des produits nautiques varient de 76 à 123 ppm et atteignent 151 ppm dans les autres secteurs; la limite actuelle d'exposition à court terme de 100 ppm a été dépassée dans au moins 48 % des échantillons personnels prélevés dans les usines de fabriction de bateaux et dans 30 % des échantillons provenant d'usines ne fabricant pas de bateaux. Dans l'ensemble de l'industrie, environ 70 % des échantillons personnels dépassaient une valeur de 50 ppm. L'utilisation d'équipement de protection des voies respiratoires était réduite au minimum. Les causes de l'exposition au styrène et l'efficacité des mesures de contrôle dans l'ensemble de l'industrie font l'objet d'un examen.

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# Book Review

**The Noise Handbook. Edited by W. Tempest. Academic Press Inc., 1985 Price $95.25 (Canadian Funds).**

This new textbook is a welcome source of information to the reader looking for a current review of the literature on this topic. The fourteen international contributors have been well selected and schooled by the editor, and, as a result, the text flows as if written by a single author, so it is easy to read and assimilate. Furthermore, it is a pleasing and well-produced publication.

Chapter 1 briefly reviews noise measurement and present-day instrumentation. The next five chapters are concerned with noise and health effects, communication, efficiency and annoyance. The subject matter is well reviewed and discussed, and the reader is reminded that our present state of knowledge is inadequate. The effects of noise are complex and usually involve several mechanisms, so more research is required to give us a better understanding. Chapters 7 to 10 review noise in industry, the home and with transportation. The problem from noise has been recognized for many years, but in spite of this, progress with attenuation has been inadequate. The final four chapters therefore deal, quite naturally, with noise control, and include interesting and extensive reviews of the law in the United Kingdom, United States and the European Economic Community. As North American readers well know, the law regarding noise control, which is diverse and extensive, is compounded by federal, state, provincial and city statutes. The protocol adopted by the European Economic Community with directives that 'bind any member state to which they are addressed, as to the result to be achieved, while leaving to domestic agencies a competence as to form and means' would seem to be a rational approach. The directive initiatives on environmental noise in both the workplace and the external environment will lead to the general adoption of overdue corrective measures.

This book, as its editor suggests, should be of value to a wide audience, including health professionals, public health and factory inspectors, lawyers, sociologists, as well as teachers, students and research workers in this field. *The Noise Handbook* can be recommended as good reading for all.

*P.L. Pelmear*

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| March 10 – 14, 1986 | 37th Pittsburgh Conference & Exposition on Analytical Chemistry and Applied Spectroscopy. Convention Centre, ATLANTIC CITY, NEW JERSEY. For further information contact: Mrs. Alma Johnson, Program Secretary, 12 Federal Drive, Suite 322, Pittsburgh, Pennsylvania, U.S.A. 15235 |
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| September 16 – 19, 1986 | XIV International Congress on Occupational Health in the Chemical Industry. LUDWIGSHAFEN (FRG). For further information contact: Prof. Dr. Alfred M. Thiess, Corporate Medical Director, BASF Aktiengesellschaft, D-6700 Ludwigshafen (FRG). |
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